

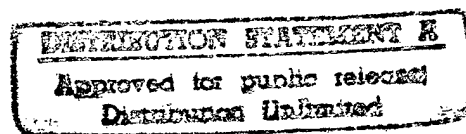
# **ENERGY SAVINGS OPPORTUNITY SURVEY**

## **ENERGY ENGINEERING ANALYSIS PROGRAM (EEAP)**

### **FORT KNOX, KENTUCKY**

#### **PREFINAL REPORT**

#### **EXECUTIVE SUMMARY**



CONTRACT # DACA27-89-C-0223

SYSTEMS/CORP PROJECT # 89027

November 7, 1990

# **SYSTEMS/CORP**

SYSTEMS ENGINEERING AND MANAGEMENT CORPORATION




DEPARTMENT OF THE ARMY  
CONSTRUCTION ENGINEERING RESEARCH LABORATORIES, CORPS OF ENGINEERS  
P.O. BOX 9005  
CHAMPAIGN, ILLINOIS 61826-9005

REPLY TO  
ATTENTION OF: TR-I Library

17 Sep 1997

Based on SOW, these Energy Studies are unclassified/unlimited.  
Distribution A. Approved for public release.

  
Marie Wakefield,  
Librarian Engineering

## TABLE OF CONTENTS

---

	<u>Page No.</u>
1. EXECUTIVE SUMMARY .....	1 - 1
1.1 Synopsis .....	1 - 1
1.2 Introduction .....	1 - 2
1.2.1 Scope of Work .....	1 - 2
1.2.2 Organization of the Final Report .....	1 - 2
1.3 Building Data .....	1 - 3
1.4 Present and Historical Energy Consumption .....	1 - 3
1.5 Results of Projects .....	1 - 10
1.5.1 ECIP Projects Developed .....	1 - 10
1.5.1.1 ECIP 1 - Occupancy Controls .....	1 - 10
1.5.1.2 ECIP 2 - Infrared Heaters .....	1 - 10
1.5.2 Non-ECIP Projects .....	1 - 10
1.5.2.1 PECIP 1 - HVAC Controls .....	1 - 11
1.5.2.2 PECIP 2 - Interior Lighting .....	1 - 11
1.5.2.3 PECIP 3 - Boiler and Piping Insulation .....	1 - 11
1.5.2.4 QRIP 1 - Boiler Improvements .....	1 - 11
1.5.2.5 QRIP 2 - Weatherstripping and Caulking .....	1 - 11
1.5.2.6 OSD PIF 1 - Boiler Replacement .....	1 - 12
1.5.2.7 Air Curtain Addition .....	1 - 12
1.5.2.8 Exterior Lighting .....	1 - 12
1.5.3 Energy and Cost Savings .....	1 - 14

19971023 168

## LIST OF TABLES

---

	<u>Page No.</u>
Table 1.3.1      List of Building Types .....	1 - 4
Table 1.4.1      Energy Consumption and Cost Comparison .....	1 - 5
Table 1.5.1      Summary of Project Data .....	1 - 13

DTIC QUALITY INSPECTED 2

\_\_\_\_\_

Page No.

## LIST OF FIGURES

---

	<u>Page No.</u>
Figure 1.5.3.16	Energy Savings by Fuel Type (Project 7) . . . . . 1 - 30
Figure 1.5.3.17	Energy Savings by Fuel Type (Project 8) . . . . . 1 - 31
Figure 1.5.3.18	Energy Savings by Fuel Type (Project 9) . . . . . 1 - 32
Figure 1.5.3.19	Energy Savings by Fuel Type (Project 10) . . . . . 1 - 33
Figure 1.5.3.20	Total Discounted Savings and Investment Cost by Project . . 1 - 34
Figure 1.5.3.21	Construction Costs by Project . . . . . 1 - 35
Figure 1.5.3.22	SIR by Project . . . . . 1 - 36
Figure 1.5.3.23	Simple Payback by Project . . . . . 1 - 37
Figure 1.5.3.24	Project Schedule . . . . . 1 - 38

# **1 EXECUTIVE SUMMARY**

---

## **1.1 SYNOPSIS**

The purpose of this project is to perform an in-depth energy analysis of 340 buildings located on the Army installation at Fort Knox, Kentucky. In addition, the project includes an exterior lighting survey of 28 locations around the facility and a comprehensive efficiency survey of 40 boilers serving 50 buildings on the Post.

A field survey of 120 buildings (representing 43 functional building types) was performed in order to evaluate selected energy conservation opportunities (ECO's) and to develop other energy conservation methods. While only 120 buildings were surveyed, the survey results were used to represent all 340 buildings under scrutiny. This was possible due to the large number of similar buildings included in the survey.

After obtaining field data, a baseline energy model of the surveyed buildings was created through computer modeling and hand calculations. This baseline represents the current energy usage of the 340 buildings. By altering the baseline model to represent a model of each ECO, an expected energy savings from implementation of each ECO was calculated. Through a joint effort by the Directorate of Engineering and Housing (DEH), SYSTEMS/CORP and the Louisville District of the U.S. Army Corps of Engineers, the recommended ECO's were grouped into 10 projects. At this point, the synergistic effects of all ECO's within each project was calculated, and complete programming and implementation documentation was completed.

The implementation of the 10 projects will reduce energy consumption on the Post by 102,850 MBTU/YR and energy costs by \$547,757 per year. Additionally, \$3,074 per year will be saved in maintenance and replacement costs for a total annual savings of \$550,831. Implementation cost (construction + SIOH) for the 10 projects is \$1,003,522 and the total net discounted savings is \$5,563,485 yielding an overall savings-to-investment ratio of 5.54 and a simple payback period of 1.82 years.

# **1 EXECUTIVE SUMMARY**

---

## **1.2 INTRODUCTION**

### **1.2.1 Scope of Work**

Systems Engineering and Management Corporation (SYSTEMS/CORP) was contracted by the Louisville District of the United States Army Corps of Engineers in September 1989 to perform an energy savings opportunity survey (ESOS) for 340 buildings at Fort Knox, Kentucky. In addition, the project includes an exterior lighting survey of 28 locations around the facility and a comprehensive survey of 40 boilers serving 50 buildings on the the Post. A complete scope of work is included in Appendix 7.1, but the essential elements are described below:

1. Evaluate selected energy conservation opportunities (ECO's) to determine their energy savings potential and economic feasibility.
2. Conduct a limited site survey of selected buildings or areas to insure that any methods of energy conservation which are practical and have not been evaluated in any previous energy study have been considered and the results documented.
3. Determine efficiency of selected boilers by testing where appropriate. Determine if boiler efficiency can be improved, or fuel saved, by the repair, addition or modification of equipment, control systems and maintenance practices and recommend improvements.
4. Provide complete programming or implementation documentation for all recommended ECO's.
5. Prepare a comprehensive report to document the work performed, the results and the recommendations.

### **1.2.2 Organization of the Final Report**

The submitted material for this report consists of the following:

Energy Savings Opportunity Survey  
Energy Engineering Analysis Program (EEAP)  
Fort Knox, Kentucky

FINAL REPORT



## **1 EXECUTIVE SUMMARY**

---

- Volume 1 - Executive Summary, Organization of Work, Methods and Approach
- Volume 2 - ECIP Project Documentation  
NON-ECIP Project Documentation
- Volume 3 - NON-ECIP Project Documentation (continued)
- Volume 4 - Narrative Summary of ECO Analysis, Appendices

### **1.3 BUILDING DATA**

Although the survey included 340 buildings, the field survey was limited to 120 buildings representing 43 functional building types. For a list of building types see *Table 1.3.1*. The field survey results were used to represent all 340 buildings due to the similarity in many of the buildings. For a detailed listing of field surveyed buildings sorted by type and size, see *Table 2.1.1.1* of the Final Report, Volume 1, pages 2 -2 through 2 - 16. For a summary of all buildings in the survey, see *Table 2.1.1.2* of the same volume, pages 2 - 17 through 2 - 20.

### **1.4 PRESENT AND HISTORICAL ENERGY CONSUMPTION**

The present energy consumption was modeled through manual calculations and the microcomputer version of "Building Loads and Energy Performance Program, DOE 2.1c." A comparison of the total base energy versus the project scope baseline energy is shown in *Table 1.4.1* and *Figure 1.4.1* through *Figure 1.4.4*. The close correlation in project percent of total base energy consumption and energy dollars indicates that a good cross-section of buildings on the Post was selected for inclusion in the survey.

**TABLE 1.3.1**

<b>BUILDING TYPE</b>	<b>BUILDING DESCRIPTION</b>
1	OFFICE
2	COMMISSARY
3	BARRACKS WITH DINING
4	FAMILY HOUSING NON COMMISSIONED OFFICERS
5	BARRACKS WITHOUT DINING
6	HOSPITAL ANNEX
7	BARRACKS/ADMINISTRATION
8	ADMINISTRATION GENERAL PURPOSE
9	FAMILY HOUSING COLONEL
10	COMM CENTER
11	BARRACKS WITH DAS
12	FAMILY HOUSING GENERAL
13	MAINTENANCE INSTRUCTION FACILITY
14	APPLIED INSTRUCTION BUILDING
15	ADMINISTRATION INSTRUCTION
16	OFFICERS QUARTERS
17	SENIOR ENLISTED QUARTERS
18	VEHICLE MAINTENANCE SHOP
19	GENERAL STOREHOUSE
20	GENERAL INSTRUCTION BUILDING
21	S-3 ANNEX
22	OPEN DINING NON COMMISSIONED OFFICERS
23	OFFICERS QUARTERS EXECUTIVE BRANCH
24	AIR CRAFT HANGER
25	AIR CRAFT MAINTENANCE SHOP
26	BARRACKS BASIC TRAINING
27	RECREATION BUILDING
28	STORAGE
29	PRIVATE CLUB
30	ADMINISTRATION
31	DINING FACILITY
32	DAY ROOM
33	CULINARY ARTS
34	CLASSROOM
35	DAY ROOM/STORAGE
36	SUPPLY ROOM
37	ADMINISTRATION/STORAGE
38	CHAPEL CENTER FACILITY
39	PHOTO LAB
40	ORDERLY ROOM
41	SUPPLY/CLASSROOM
42	CLINIC
43	ARMOR CREW TRAINING

# Energy Consumption and Cost Comparison

	Total Base (MBTU)	Project Scope (MBTU)	Project as % of Total	Total Base (\$)	Project Scope (\$)	Project as % of Total
Natural Gas	1,703,925	496,560	29.1	6,104,759	1,881,962	30.8
Electric	613,718	187,260	30.5	7,566,621	2,473,705	32.7
Fuel Oil	285,477	76,747	26.9	1,243,330	370,688	29.8
TOTAL	2,603,120	760,567	29.2	14,914,710	4,726,355	31.7

TABLE 1.4.1

# Energy Consumption Total Base vs. Project Scope (MBTU)

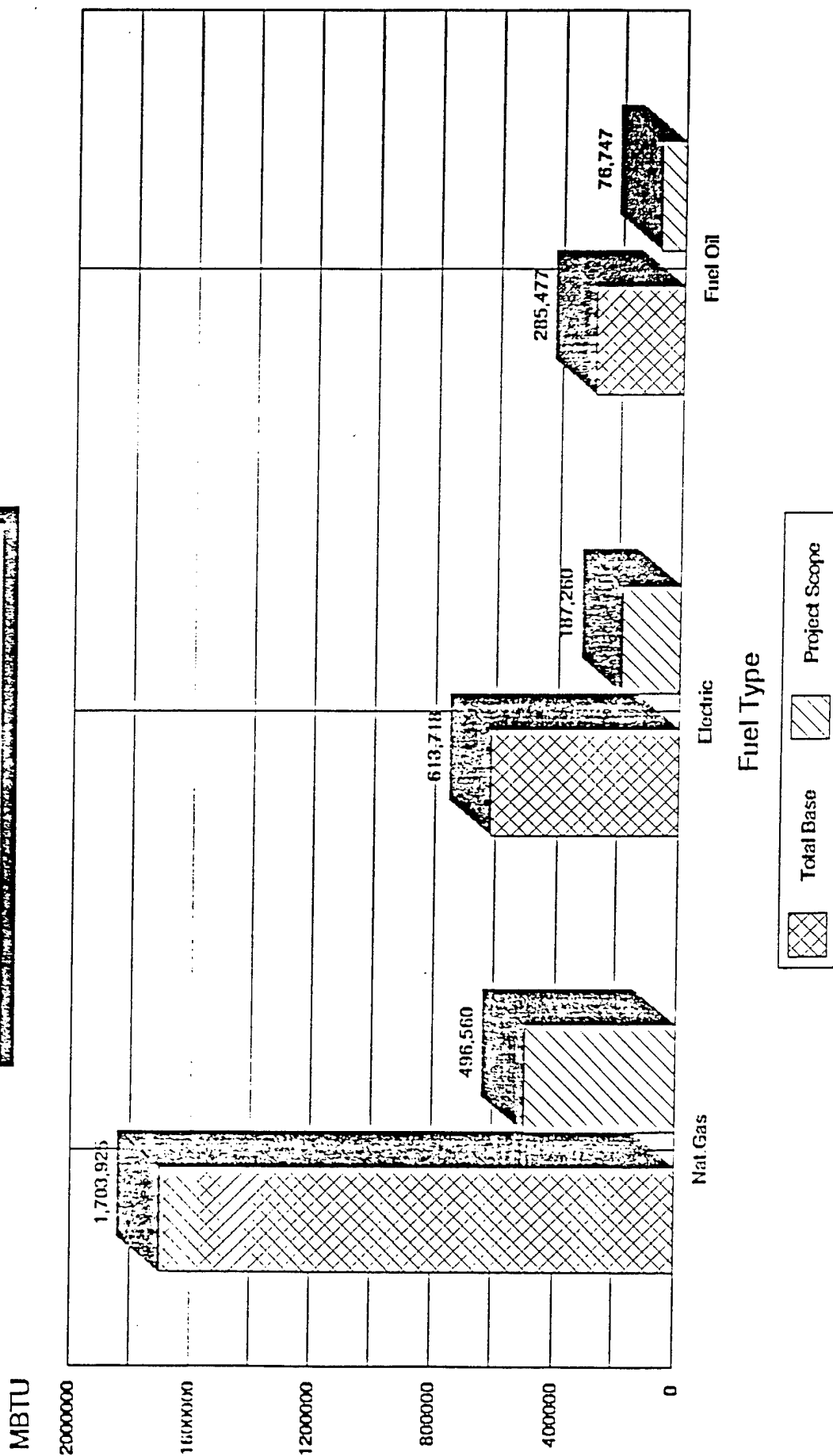
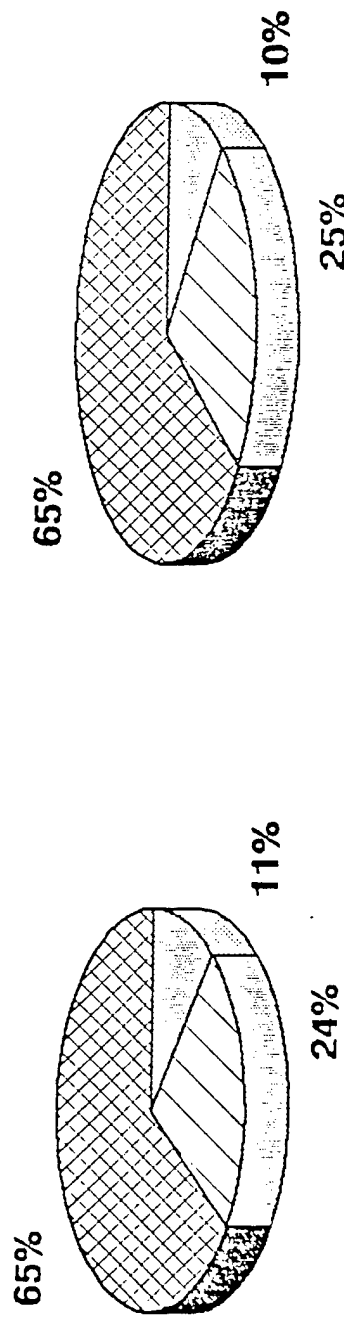


FIGURE 1.4.1

# **Energy Consumption Total Base vs. Project Scope (MBTU)**

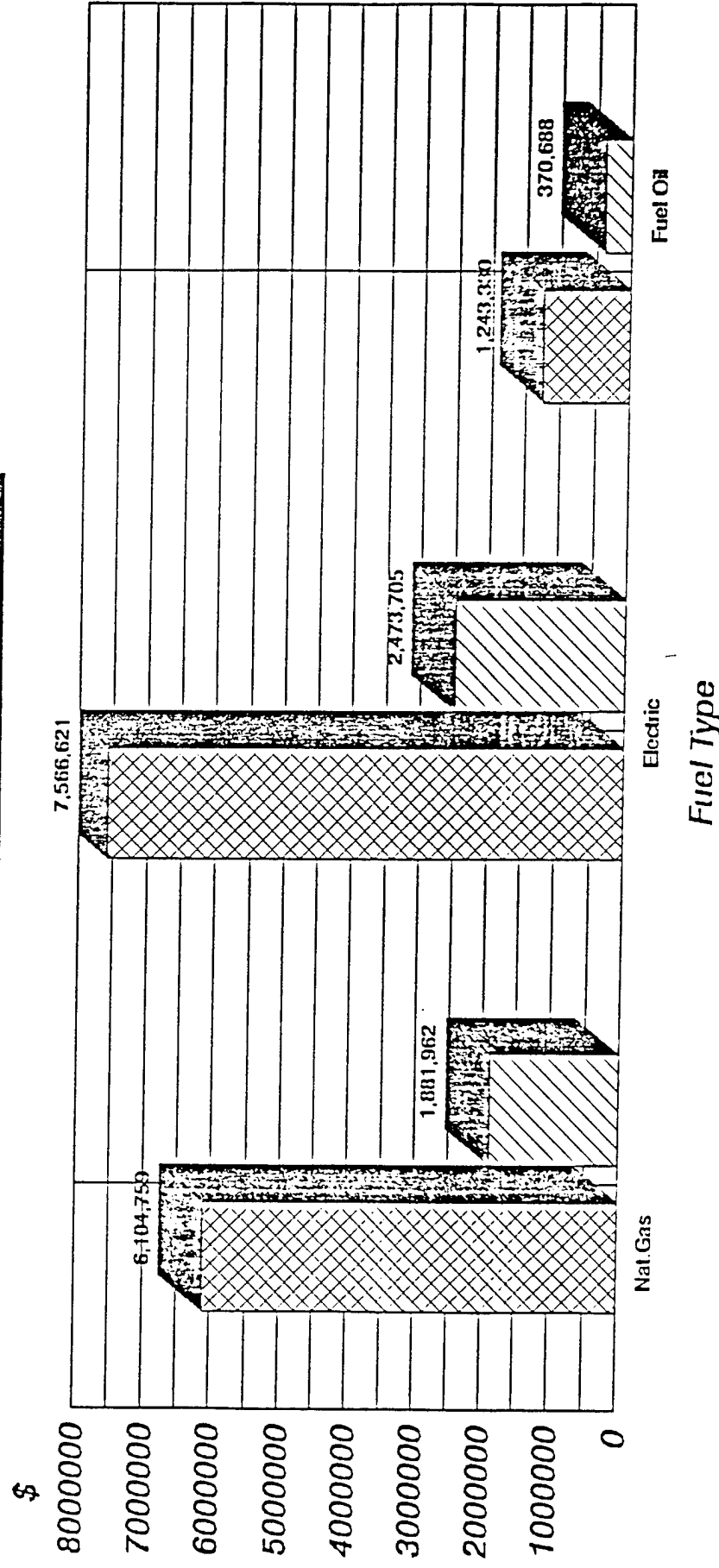


**Total Base                      Project Scope**



FIGURE 1.4.2

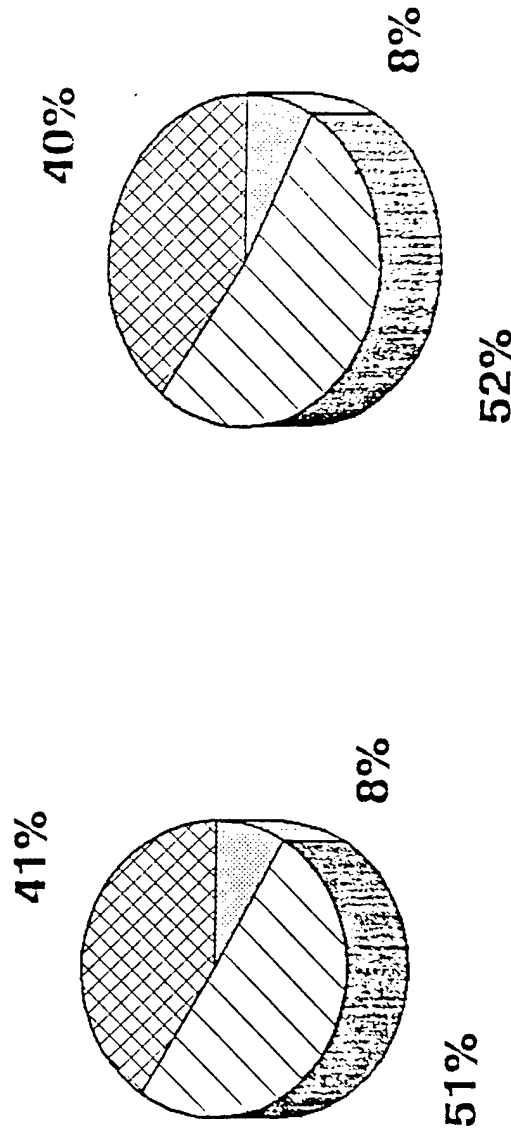
# Energy Cost Total Base vs. Project Scope (\$)



Nat. Gas: \$3.79/MBTU; 3.09/MCF  
Electric: \$13.21/MBTU; .0451/KWH  
Fuel Oil: \$4.83/MBTU; 0.67/Gal.

FIGURE 1.4.3

# Energy Cost Total Base vs. Project Scope (\$)



**Total Base** **Project Scope**



FIGURE 1.4.4

## **1 EXECUTIVE SUMMARY**

---

### **1.5 RESULTS OF PROJECTS**

After calculation of ECO's, recommended ECO's were grouped into 10 projects. For a brief summary and description of each project, see *Table 1.5.1*.

#### **1.5.1 ECIP Projects Developed**

Two Energy Conservation Investment Program Funding (ECIP) projects were developed. Complete programming and implementation documentation for each ECIP appears in Volume 2 of the Final Report.

##### **1.5.1.1 ECIP 1 - Occupancy Controls**

ECIP 1 involves the installation of occupancy controls in 10 buildings. Five buildings are bachelor officer's quarters and five are classroom-type buildings. The occupancy controls will prevent lights and air conditioning units from being left on during long periods of no occupancy.

##### **1.5.1.2 ECIP 2 - Infrared Heaters**

ECIP 2 is the installation of infrared heaters in 16 facilities containing high bay areas. These facilities include vehicle maintenance, aircraft hangars, and applied instruction buildings where bay doors are frequently opened. The use of infrared heaters will allow lower thermostat setpoints with the same level of occupant comfort, thereby reducing energy consumption.

#### **1.5.2 NON-ECIP Projects**

Eight of the ten projects qualify as non-ECIP projects. These include three Productivity Enhancing Capital Investment Program (PECIP) projects, two Quick Return on Investment Program (QRIP) projects, one OSD PIF (Office of the Secretary of Defense Productivity Investment Funding) project, and two projects which fall under no funding category. Complete programming and implementation documentation for each project appears in Volumes 2 and 3 of the Final Report.



## **1 EXECUTIVE SUMMARY**

---

### **1.5.2.1 PECIP 1 - HVAC Controls**

PECIP 1 involves HVAC control system modifications in 143 buildings. Two energy saving methods were employed: automatic setback thermostats in barracks and vehicle maintenance buildings, and electronic ignition kits for natural gas furnaces to eliminate standing pilots in a variety of building types.

### **1.5.2.2 PECIP 2 - Interior Lighting**

This project consists of three different interior lighting ECO's in a total of 24 buildings. The three energy conserving opportunities are: replacing incandescent lighting with screw-in fluorescents in barracks; replacing fluorescent lamps and ballasts with high efficiency fluorescent fixtures in officer's quarters, and replacing mercury vapor fixtures with high efficiency metal halide fixtures in one aircraft hangar.

### **1.5.2.3 PECIP 3 - Boiler and Piping Insulation**

This project conserves energy by identifying existing steam piping which is not well insulated. Steam piping insulation is added or replaced in 31 barracks and two vehicle maintenance buildings.

### **1.5.2.4 QRIP 1 - Boiler Improvements**

This project consists of boiler efficiency improvements in 79 buildings, 42 of which are basic training barracks. Other building types are officer's quarters, NCO open dining, family housing, administrative, vehicle maintenance, applied instruction, and armor crew training. Boiler efficiency is improved by cleaning boiler tubes, reducing excess air, and the installation of boiler optimizing controls.

### **1.5.2.5 QRIP 2 - Weatherstripping and Caulking**

QRIP 2 involves the addition of weatherstripping on doors and caulking around windows, joints, and other building cracks to prevent infiltration. This project applies to 11 vehicle maintenance buildings and 1 barracks/administration building.

## **1 EXECUTIVE SUMMARY**

---

### **1.5.2.6 OSD PIF 1 - Boiler Replacement**

This project combines two ECO's: installation of a smaller boiler and installation of a more efficient boiler. Smaller boilers will replace existing boilers in one communications center, one applied instruction building, and one armor crew training building. The new downsized boilers will operate at higher efficiencies under partial loads as well as full load. An existing hot water boiler will be replaced by a higher efficiency boiler in one commissary building.

### **1.5.2.7 Air Curtain Addition**

This project cannot be placed under a funding category. The project involves the installation of 6 air curtains (or air doors) on the large aircraft hangar doors of Building 5220. This results in energy savings due to the decrease in infiltration across the doorways.

### **1.5.2.8 Exterior Lighting**

This project cannot be placed under a funding category. It involves the replacement of existing mercury vapor roadway lighting with more efficient high pressure sodium fixtures.

**TABLE 1.5.1  
SUMMARY OF PROJECT DATA**

PROJECT NUMBER	PROGRAM NUMBER	DESCRIPTION	SIR	SIMPLE PAYBACK	ENERGY SAVINGS (MBTU/YR)	ANNUAL SAVINGS (\$/YR)	DISCOUNTED SAVINGS (\$/YR)
1	QRIP 1	BOILER IMPROVEMENTS	18.20	0.55	34,168	147,678	1,626,874
2	PECIP 1	HVAC CONTROLS	2.69	2.94	4,972	22,767	199,544
3	OSD PIF 1	BOILER REPLACEMENT	7.50	1.35	15,676	72,718	823,613
4	PECIP 2	INTERIOR LIGHTING	4.15	2.37	1,035	22,470	242,604
5	ECIP 1	OCCUPANCY CONTROLS	7.48	1.31	20,402	155,259	1,516,436
6	ECIP 2	INFRARED HEATERS	3.84	2.44	18,741	83,212	684,895
7	PECIP 3	BOILER AND PIPING INSULATION	3.06	3.09	4,056	16,324	171,920
8	—	AIR CURTAIN ADDITION	1.15	10.26	948	4,871	56,501
9	—	EXTERIOR LIGHTING	1.12	10.73	1,196	15,801	189,770
10	QRIP 2	WEATHERSTRIPPING & CAULKING	18.80	0.76	924	4,897	77,641

## 1 EXECUTIVE SUMMARY

---

### 1.5.3 Energy and Cost Savings

Implementation of all 10 projects will result in a savings of 102,850 MBTU/YR and \$550,831 per year. *Figure 1.5.3.1* shows that this is an 18% reduction in present energy consumption. A total discounted savings of \$5,563,485 is achieved over the life of all projects, while the implementation cost (Construction + SIOH) for all 10 projects is \$1,003,522. An overall savings-to-investment ratio of 5.54 and a simple payback period of 1.82 years are achieved from the implementation of the 10 projects. *Figure 1.5.3.2* and *Figure 1.5.3.3* show the impact of the projects by comparing energy use and cost before and after the implementation of the projects. *Figure 1.5.3.4* through *Figure 1.5.3.8* illustrate current the energy usage by project and dollar savings achieved with the implementation of each project. *Figure 1.5.3.9* through *Figure 1.5.3.19* further breakdown the project savings into fuel types. *Figure 1.5.3.20* through *Figure 1.5.3.23* indicate the economics of the projects, and *Figure 1.5.3.24* is a schedule of project implementation.

# Total Current Energy and % Energy Savings

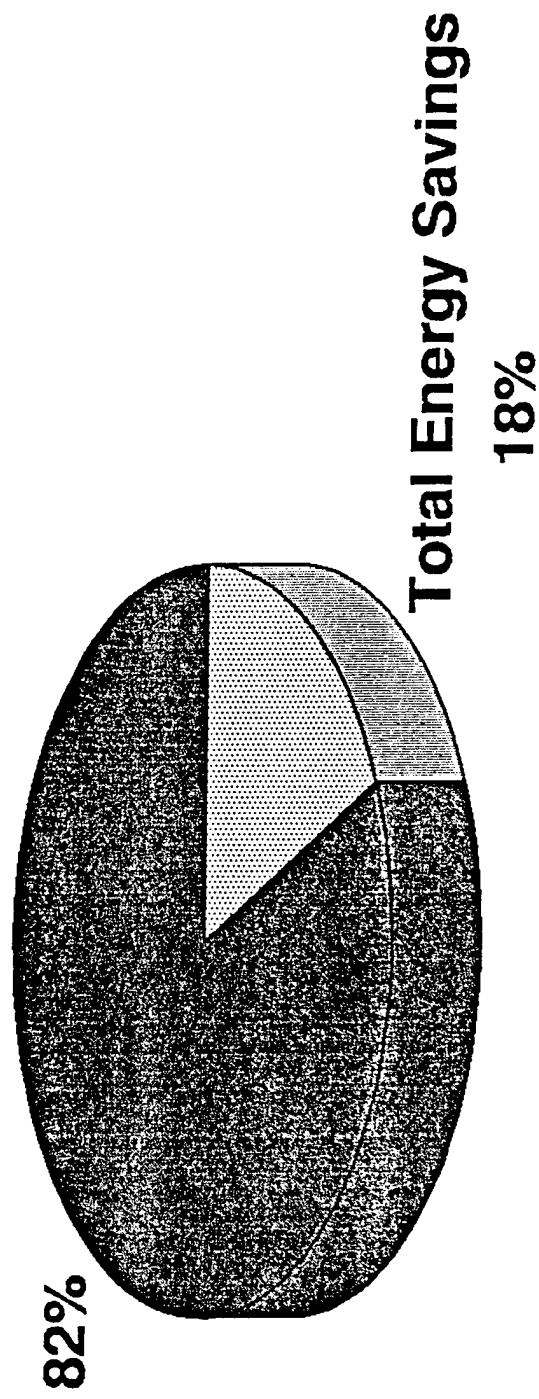


Figure 1.5.3.1

# Current Energy vs. Proposed Energy All Projects

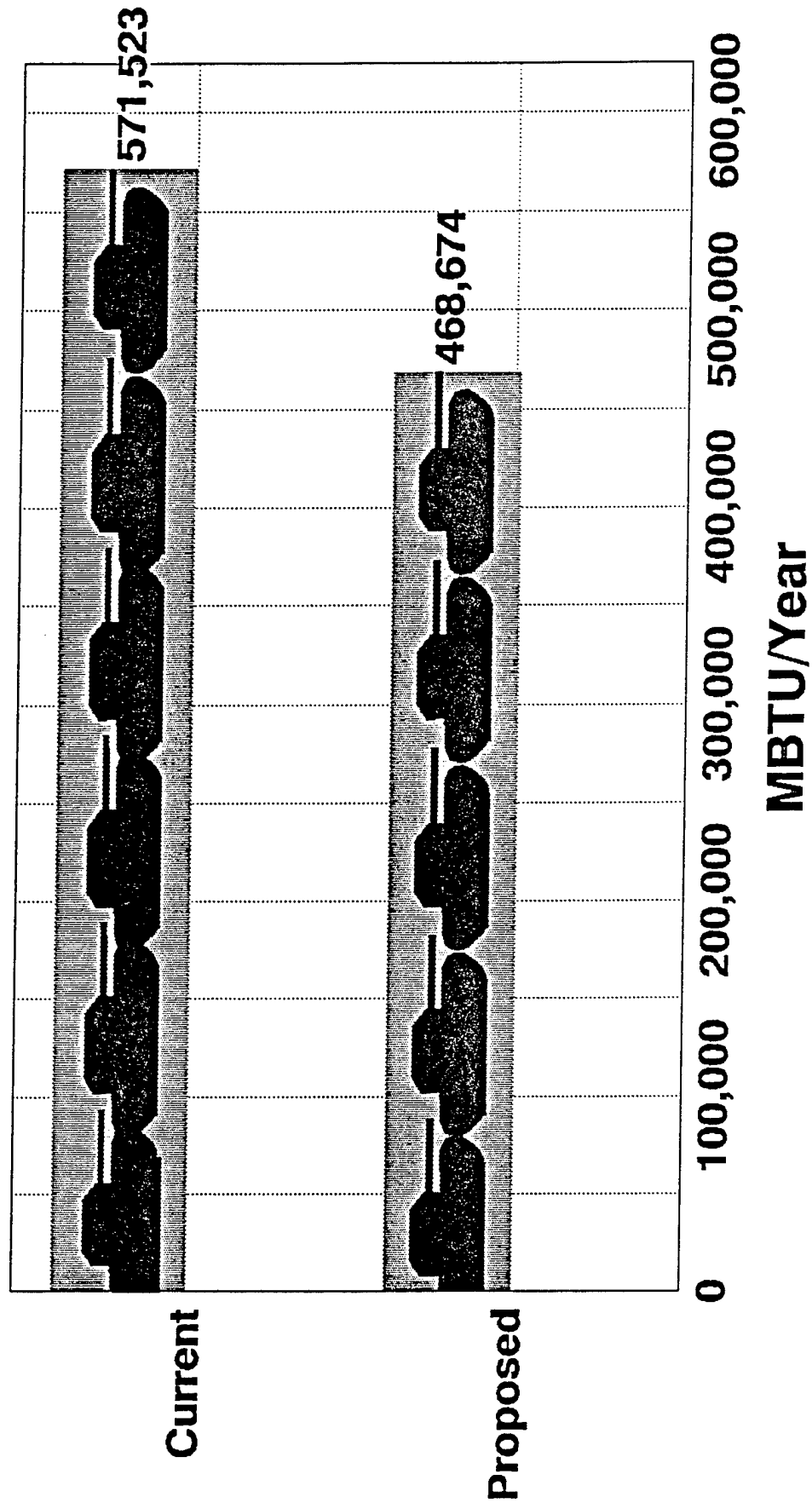


Figure 1.5.3.2

# Current Energy vs. Proposed Energy All Projects

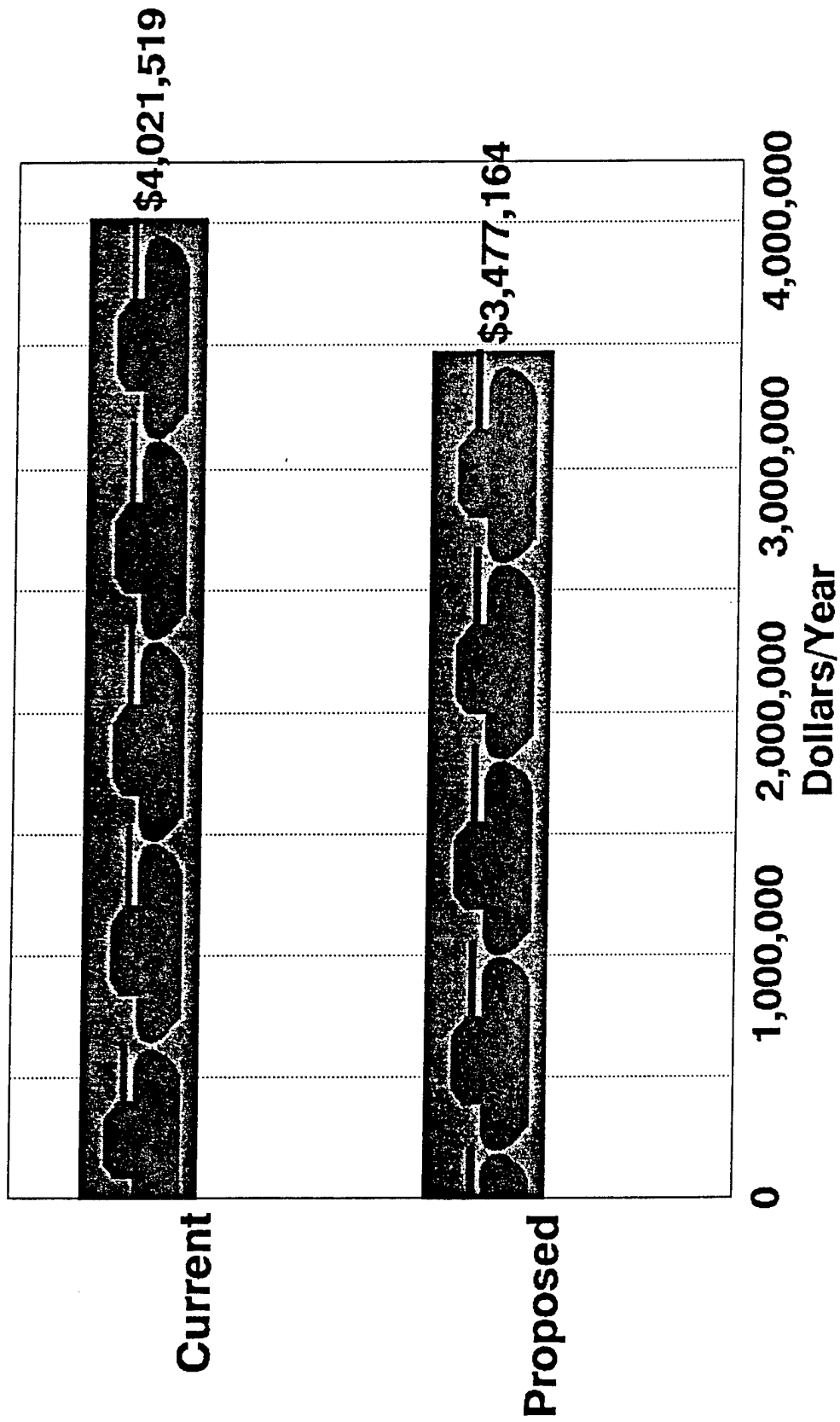


Figure 1.5.3.3

# Current Energy Consumption by Project (MBTU/Year)

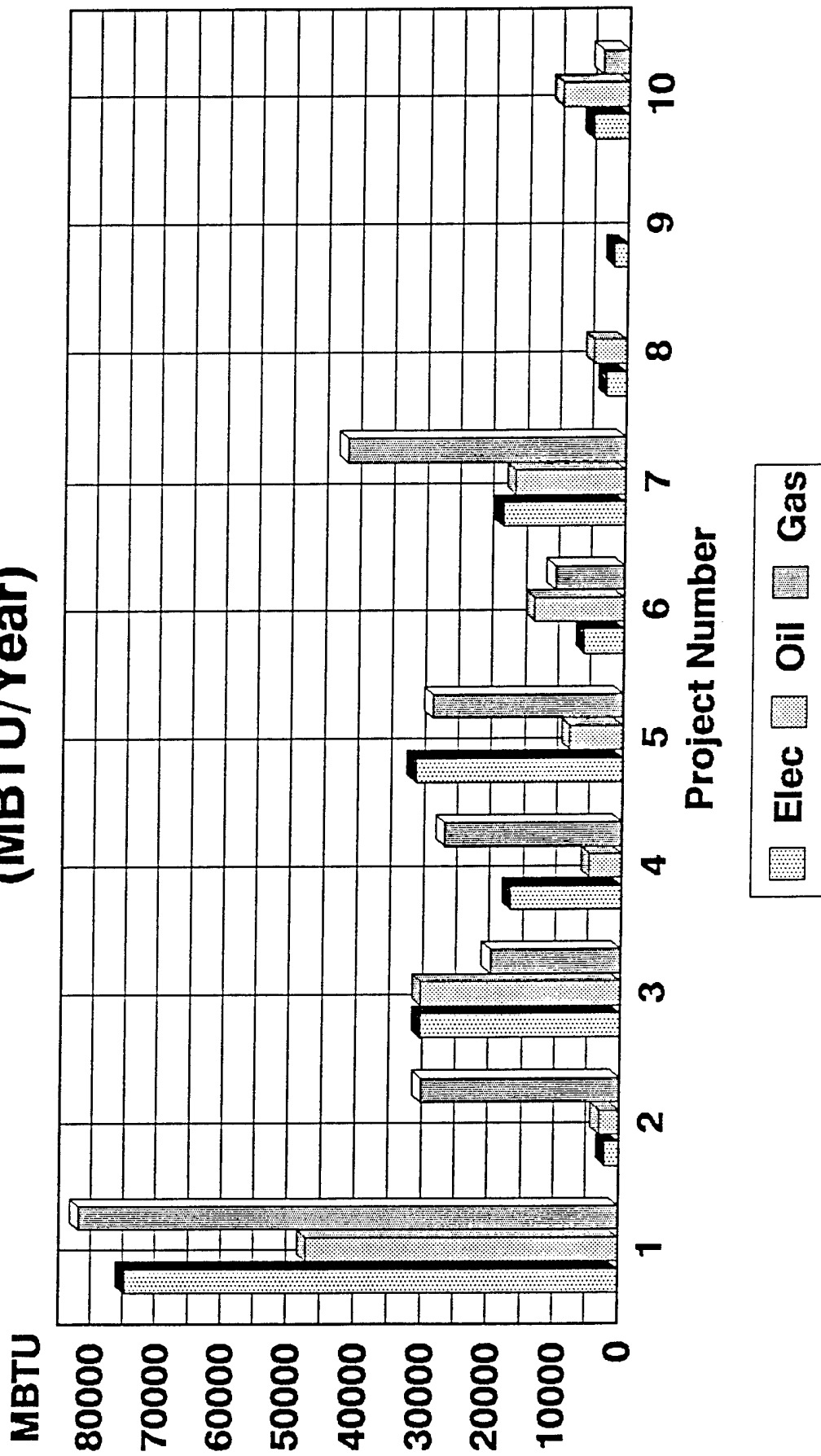


Figure 1.5.3.4



# Current Energy Consumption by Project (Dollars/Year)

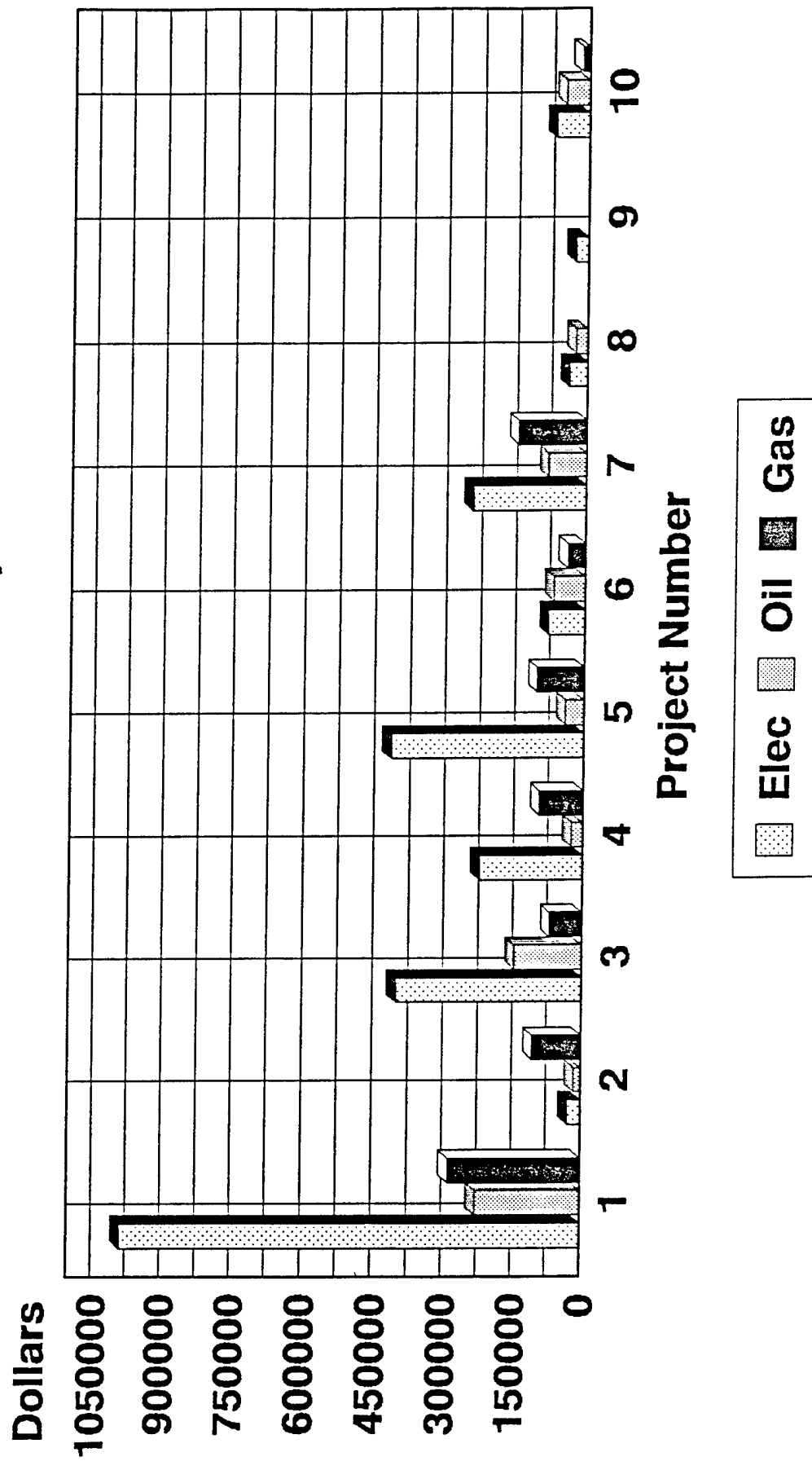


Figure 1.5.3.5

# Current Energy vs. Proposed Energy by Project

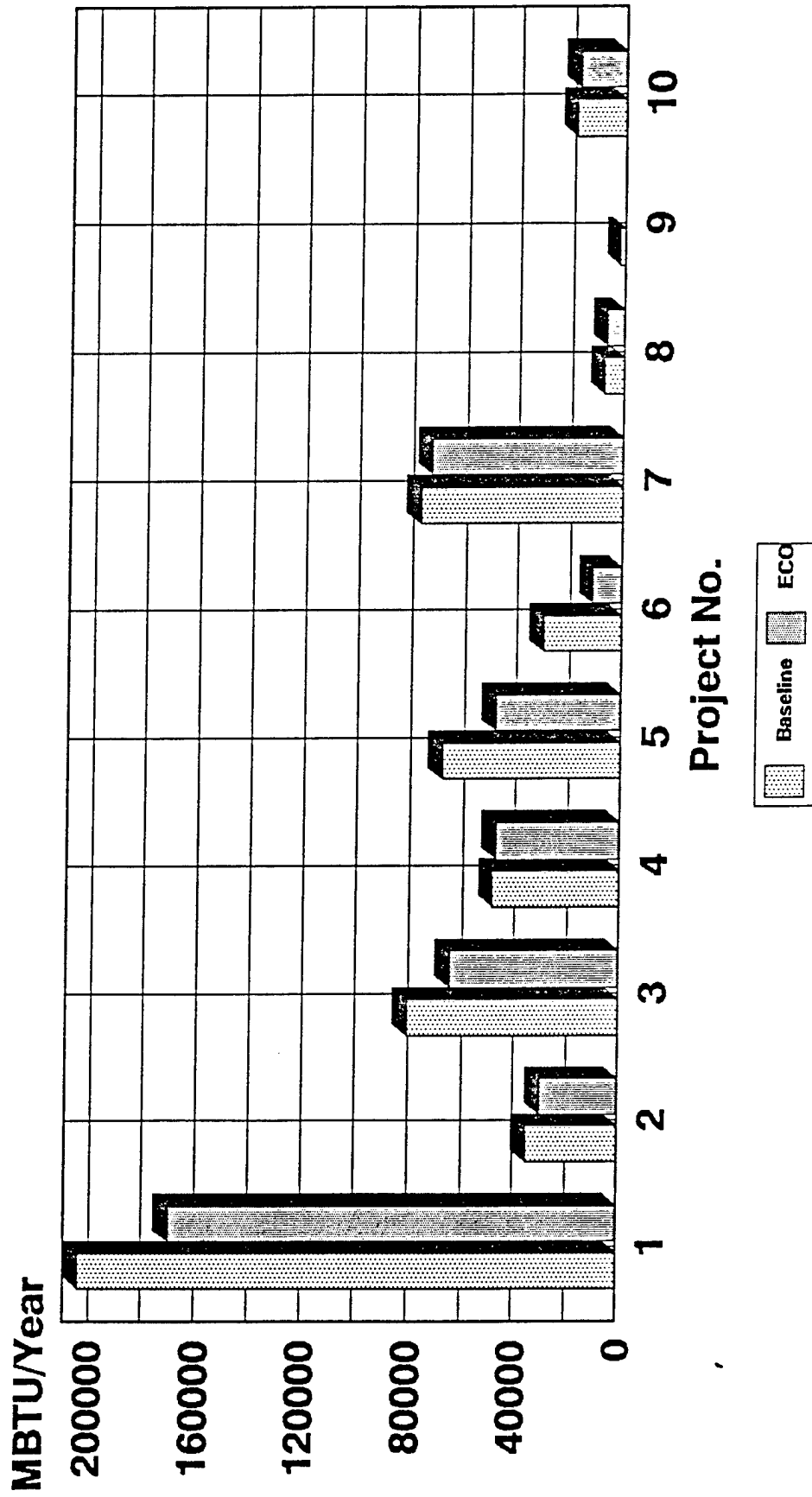


Figure 1.5.3.6

## Annual Energy Savings (MBTU) by Project

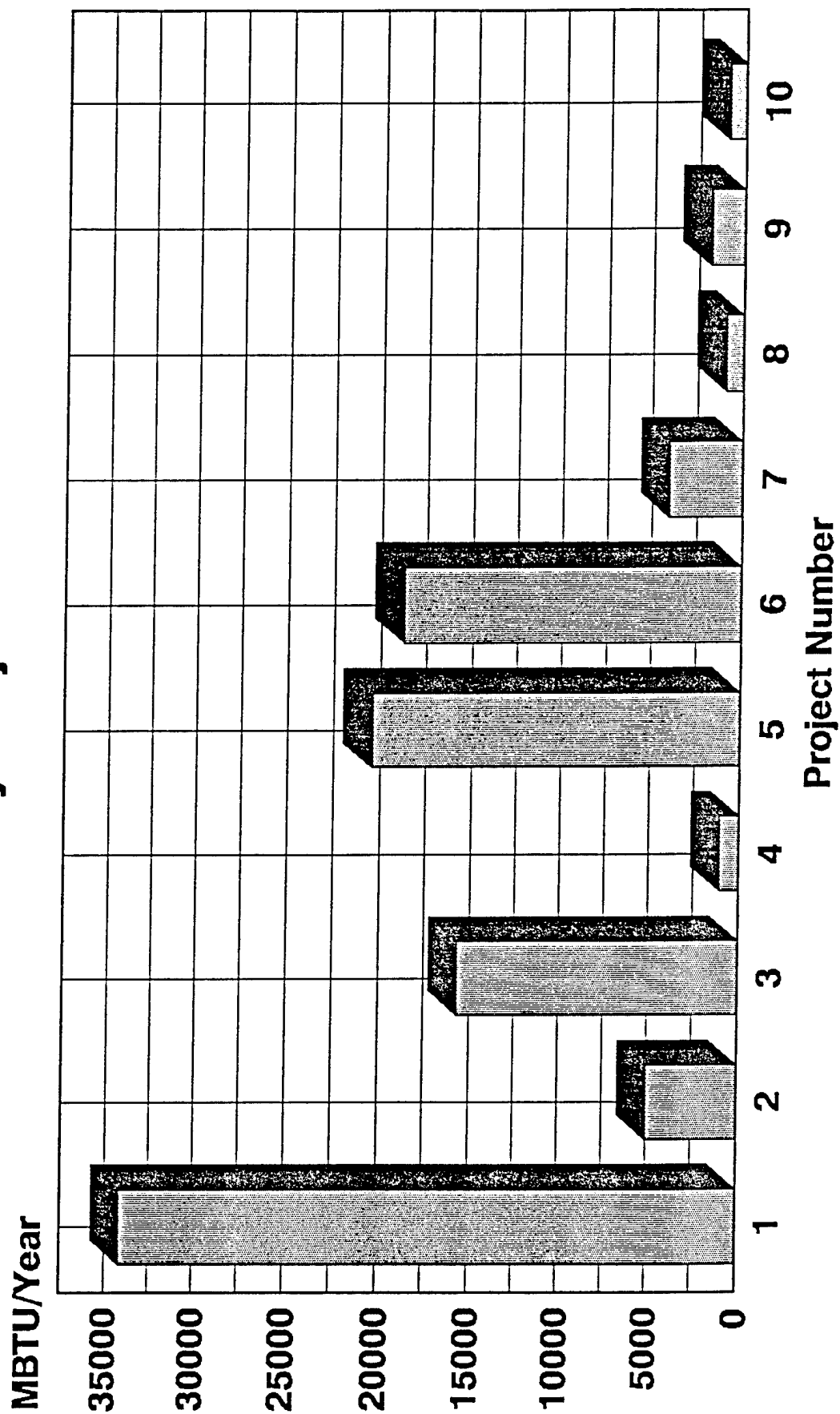


Figure 1.5.3.7

# Annual Energy Savings (Dollars) by Project

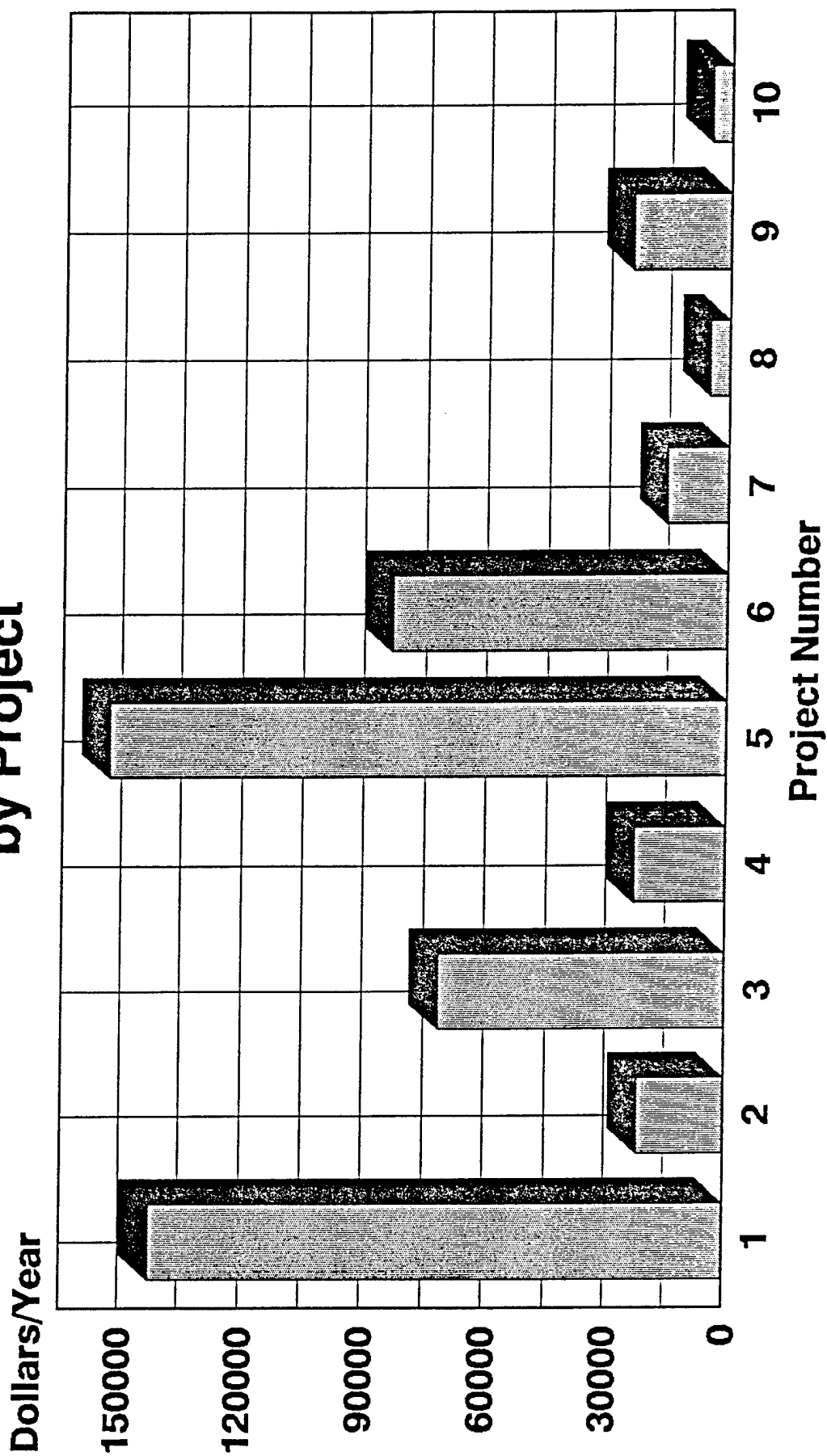


Figure 1.5.3.8

# Energy Savings by Fuel Type

## All Projects

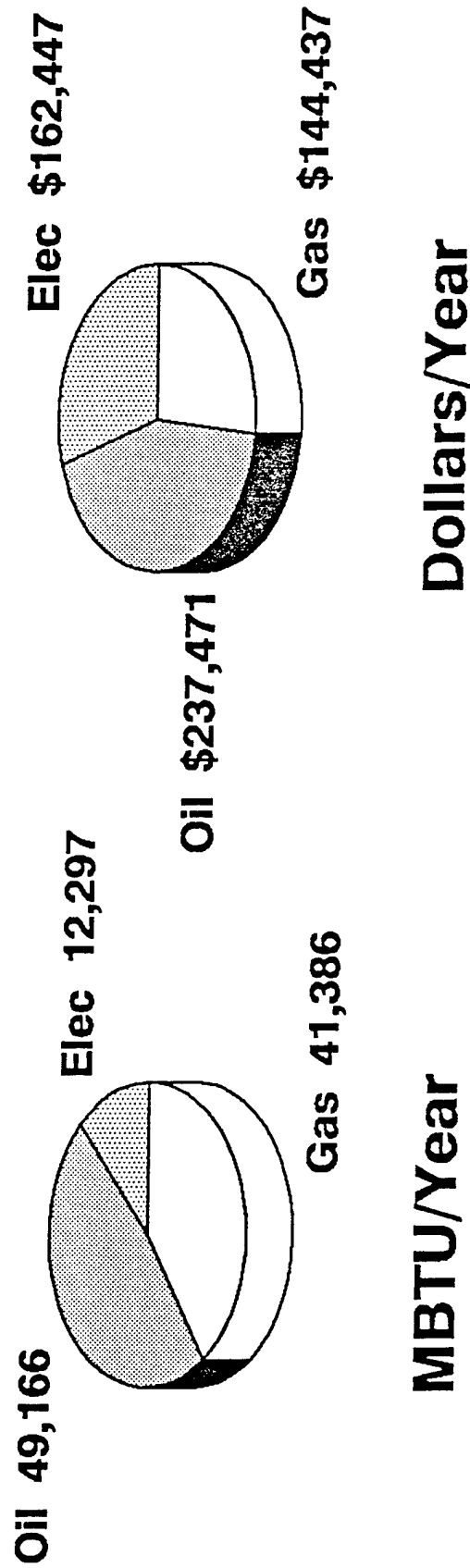


Figure 1.5.3.9

# Energy Savings by Fuel Type

## Project 1: QRIP - Boiler Improvements

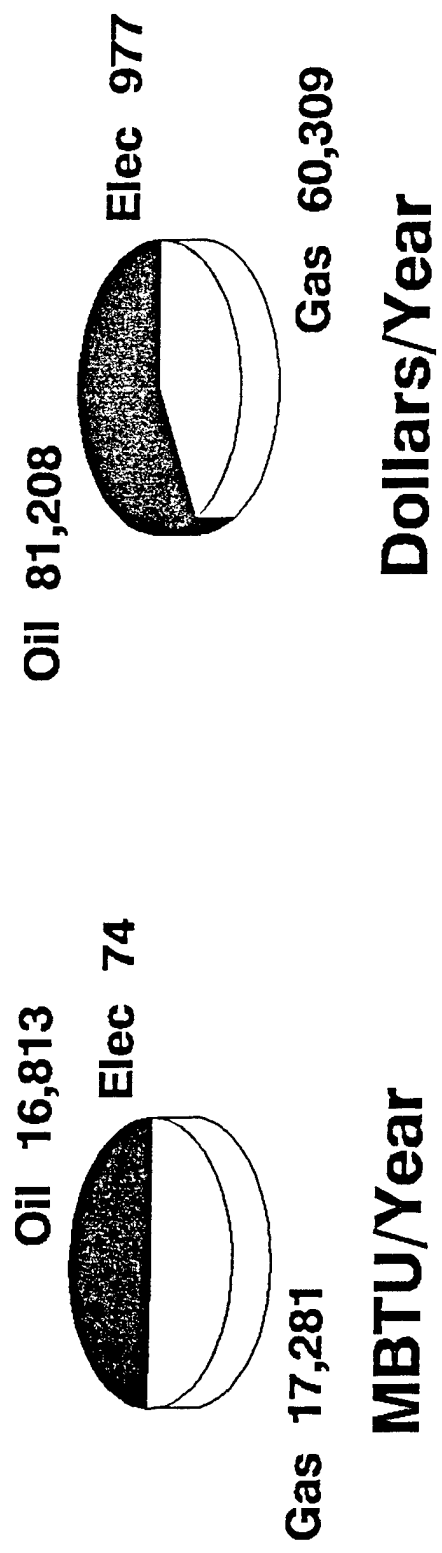
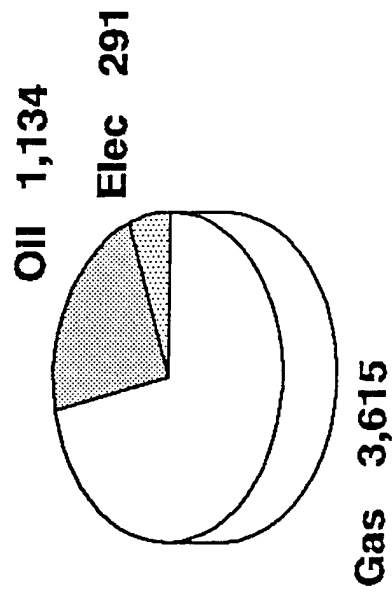


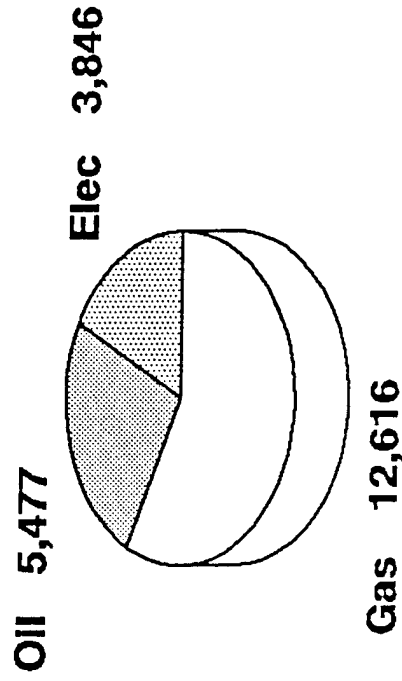
Figure 1.5.3.10

# Energy Savings by Fuel Type

## Project 2: PECIP 1 - HVAC Controls



**MBTU/Year**



**Dollars/Year**

Figure 1.5.3.11

# Energy Savings by Fuel Type

## Project 3: OSD PIF 1 - Boiler Replacement

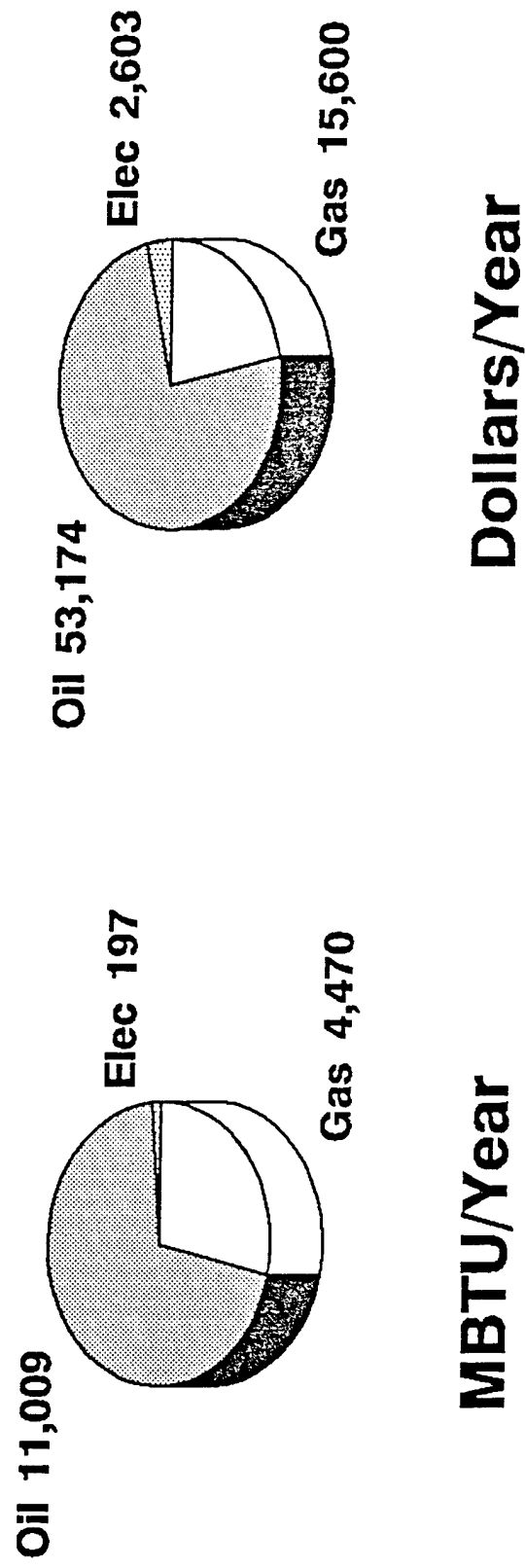
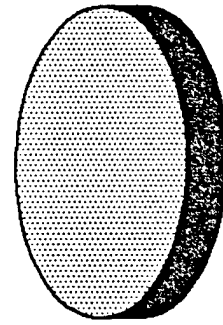


Figure 1.5.3.12



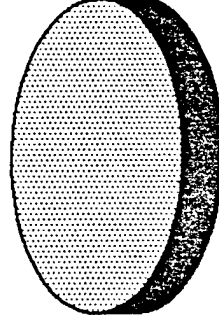
# Energy Savings by Fuel Type

## Project 4: PECIP 2 - Interior Lighting



Elec 2,012

**MBTU/Year**



Elec 26,583

**Dollars/Year**

Figure 1.5.3.13

# Energy Savings by Fuel Type

## Project 5: ECIP 1 - Occupancy Controls

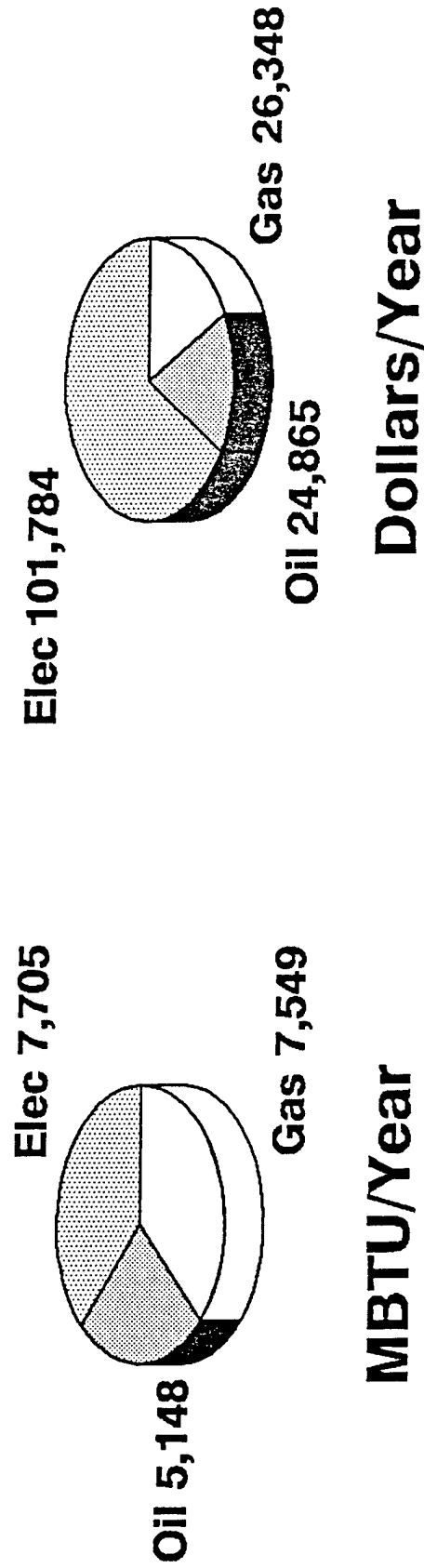


Figure 1.5.3.14

# Energy Savings by Fuel Type

## Project 6: ECIP 2 - Infrared Heaters

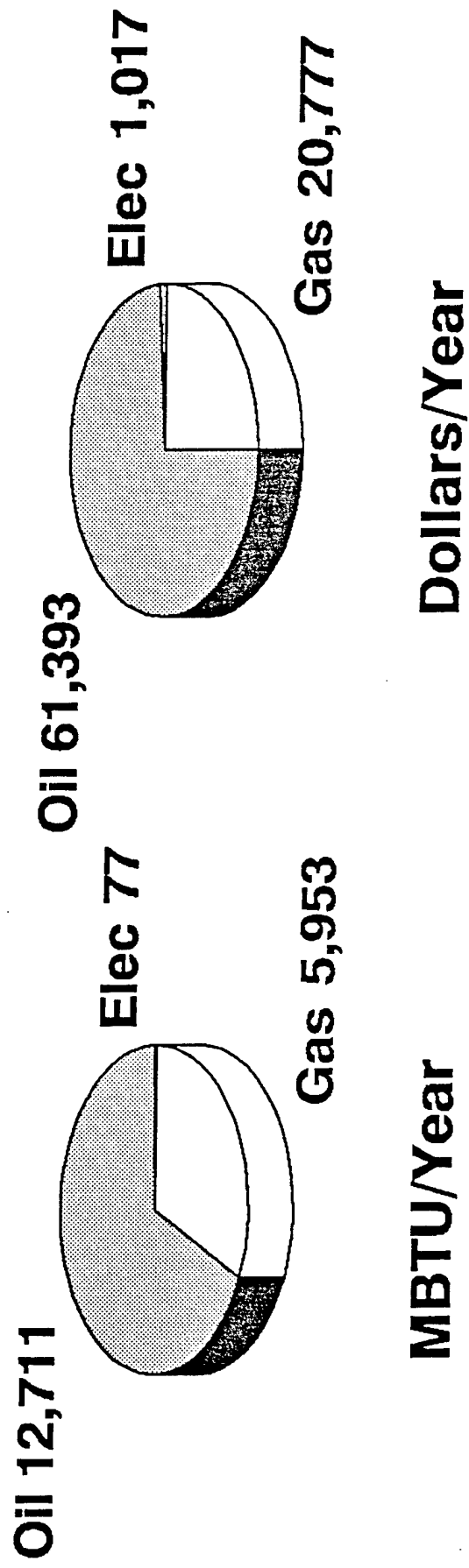


Figure 1.5.3.15

## Energy Savings by Fuel Type

### Project 7: PECIP 3 - Boiler and Piping Insulation

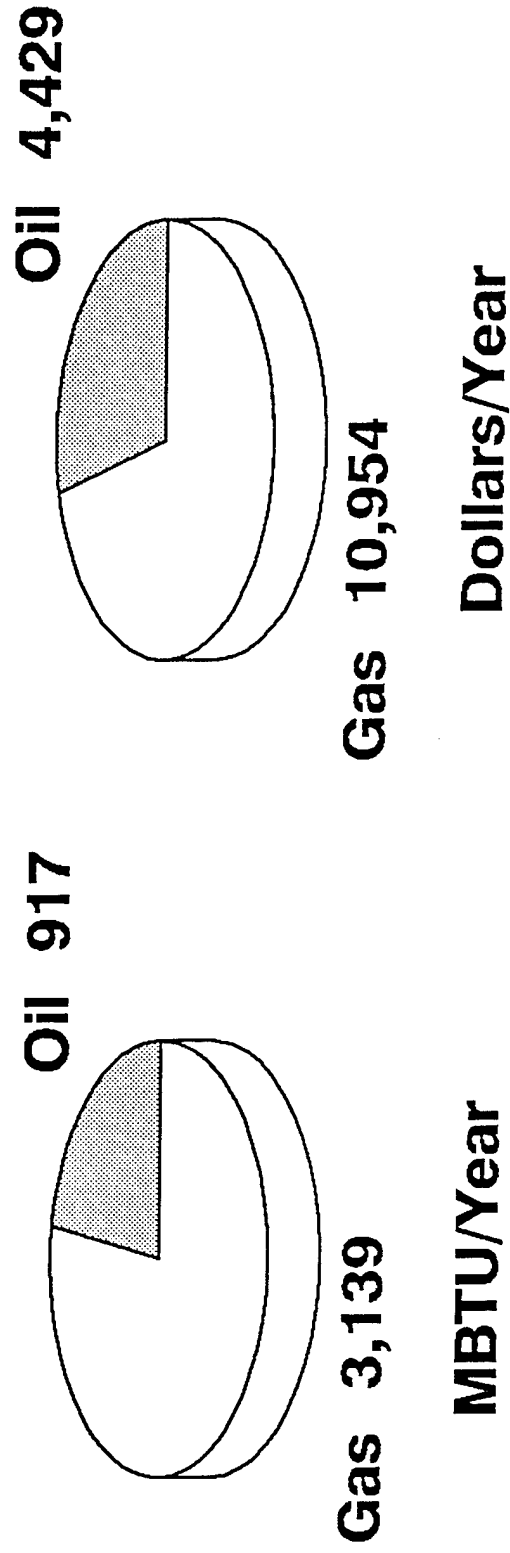


Figure 1.5.3.16

# Energy Savings by Fuel Type

## Project 8: Air Curtain Addition

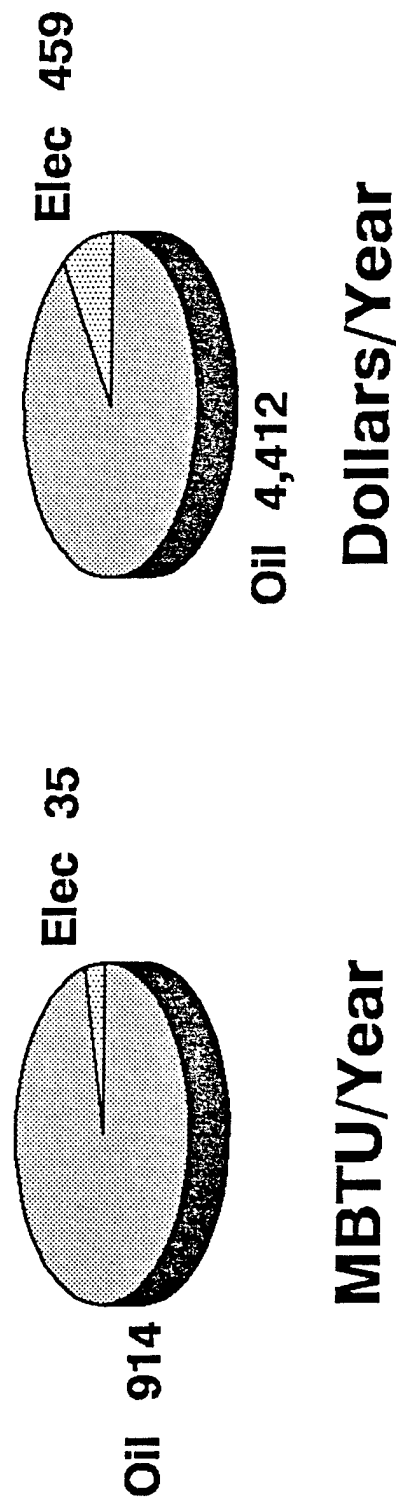


Figure 1.5.3.17

# Energy Savings by Fuel Type

## Project 9: Exterior Lighting

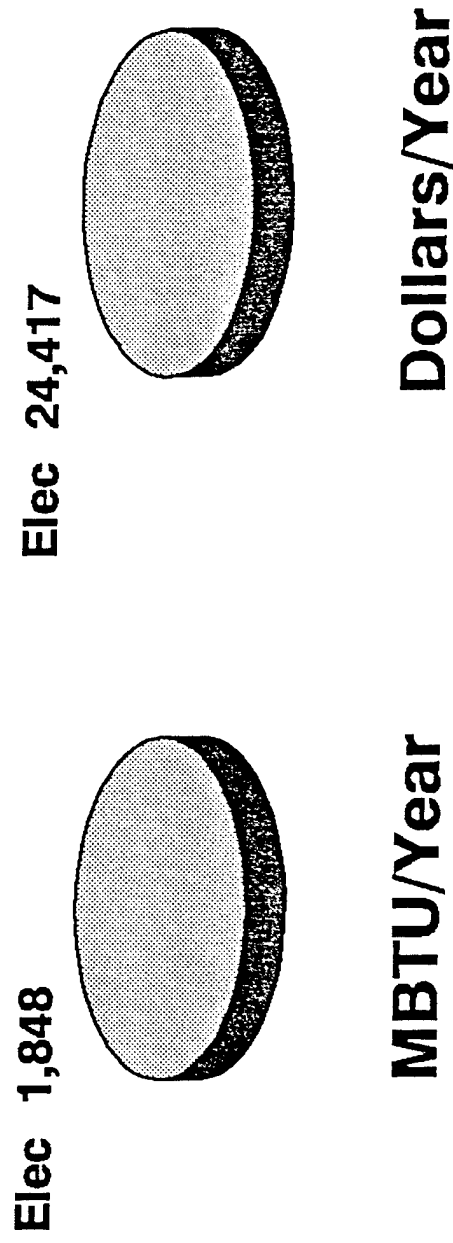


Figure 1.5.3.18

# Energy Savings by Fuel Type

## Project 10: QRIP 2

### Weatherstripping and Caulking

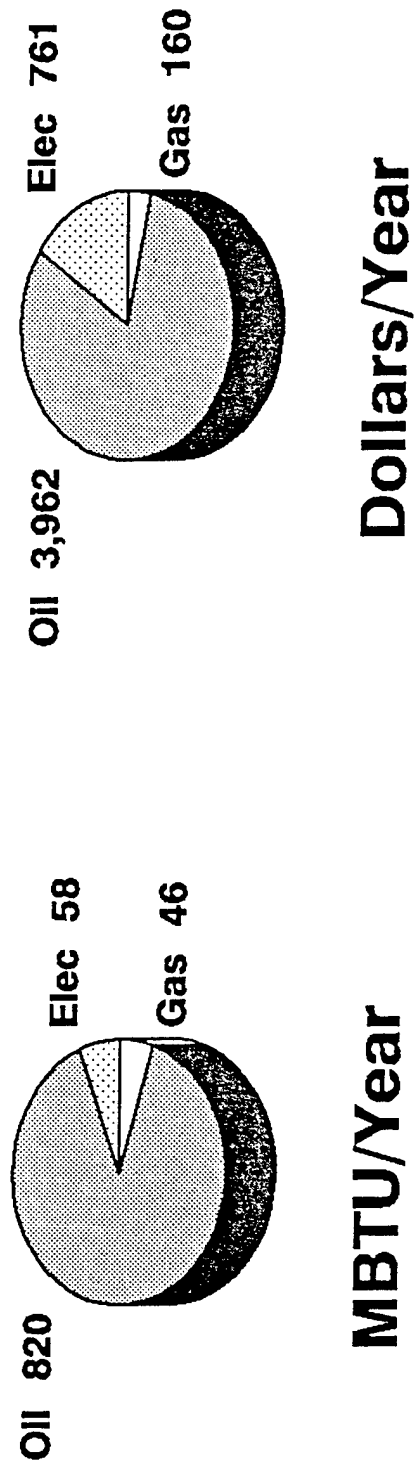


Figure 1.5.3.19

# Total Discounted Savings and Investment Cost by Project

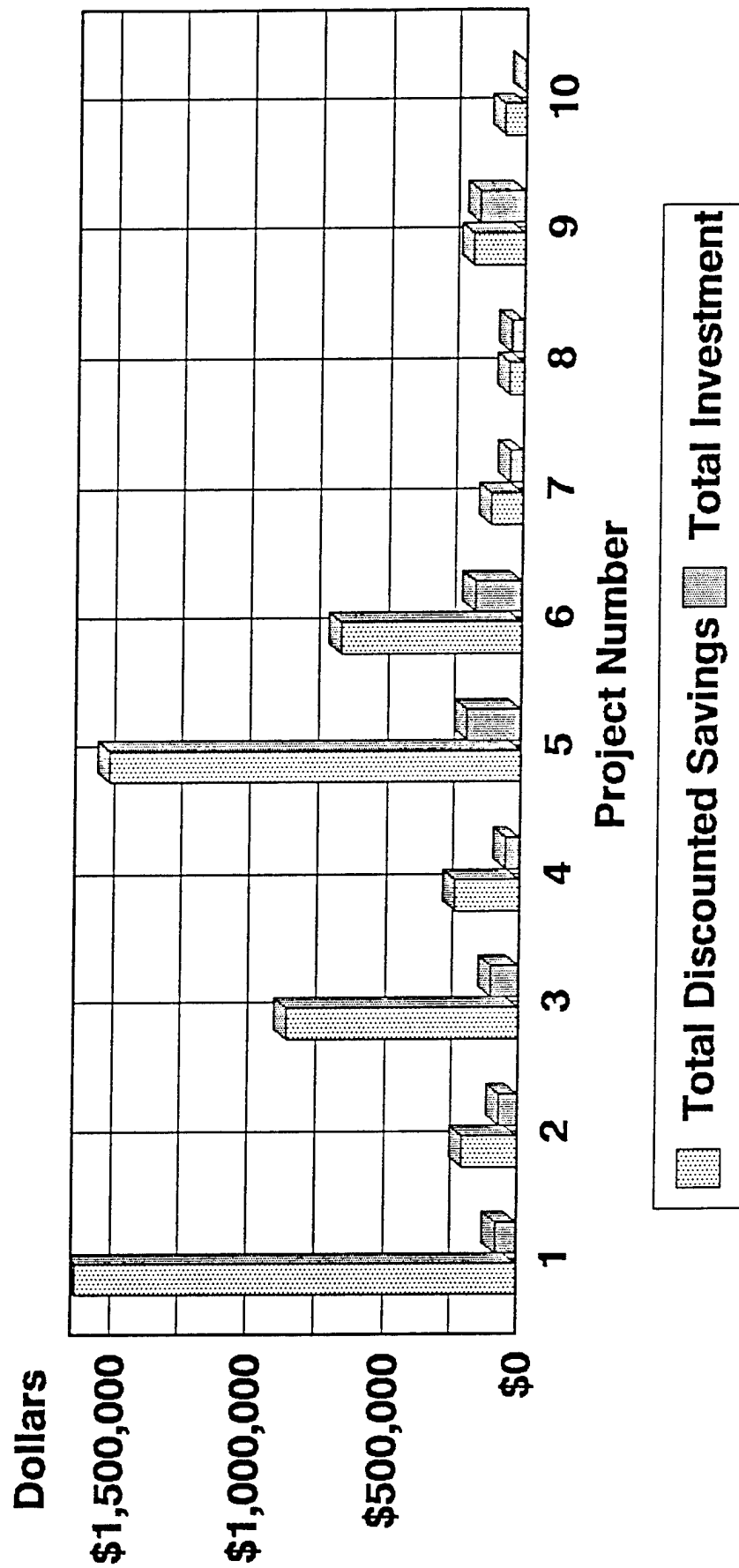


Figure 1.5.3.20



# Construction Costs by Project

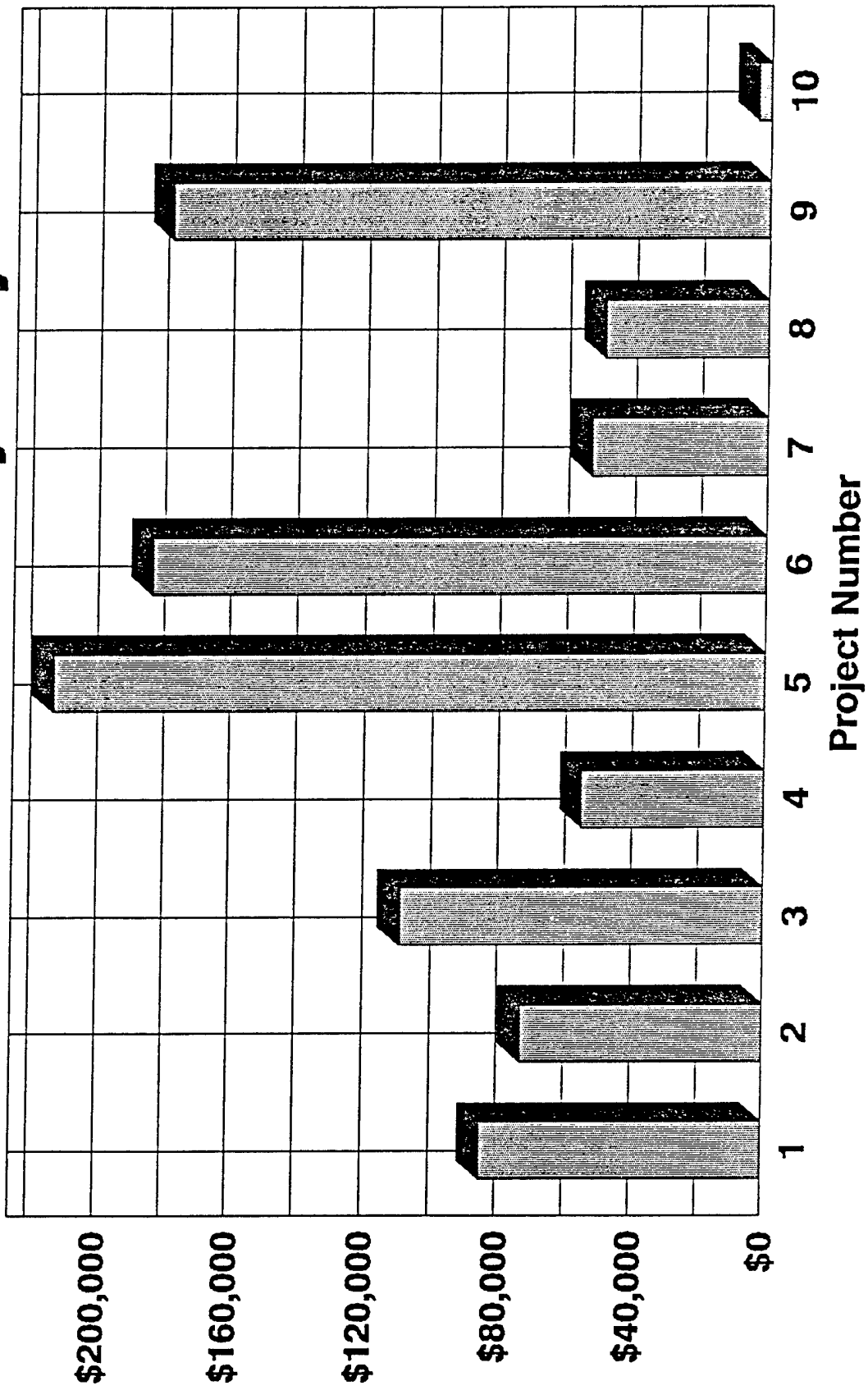
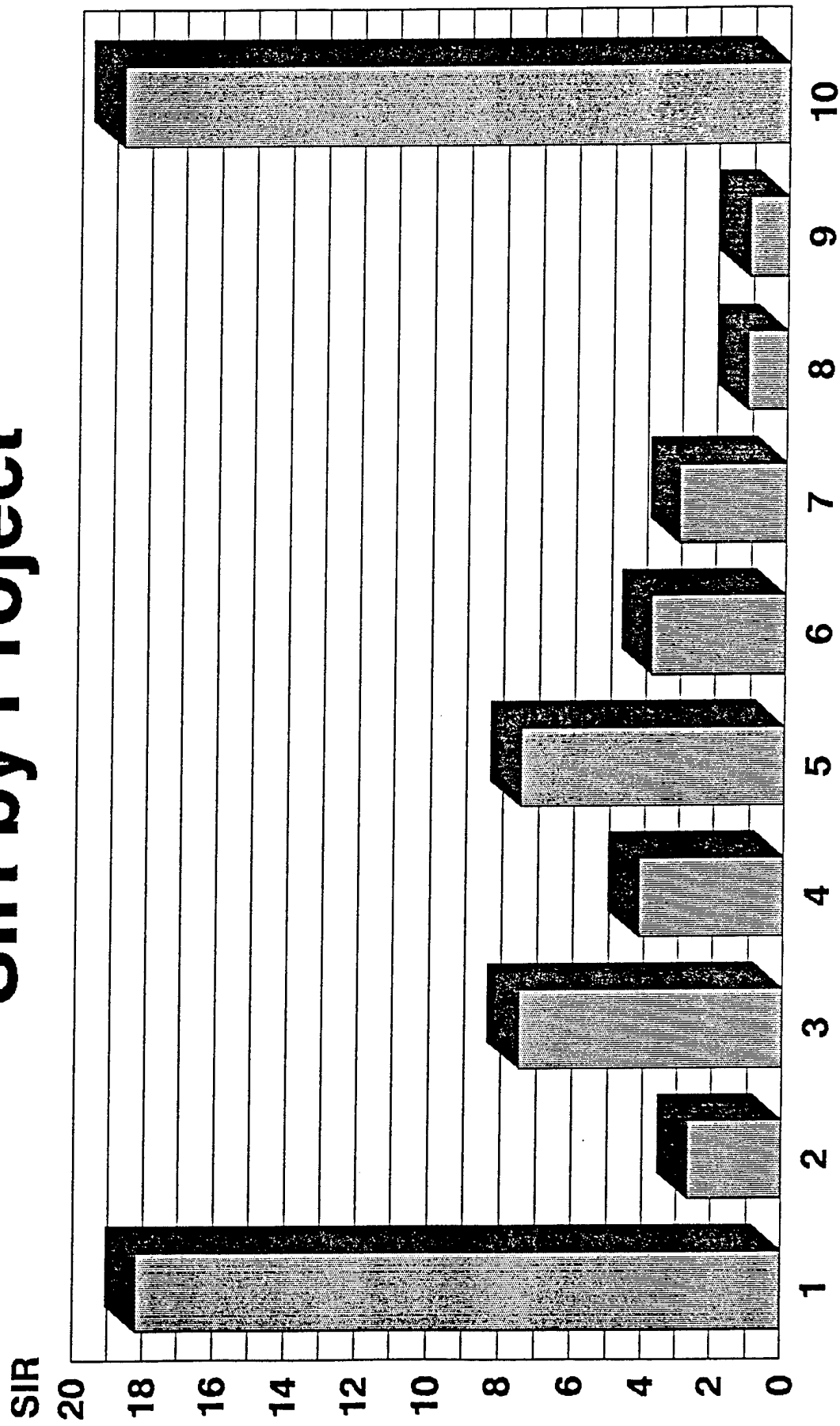


Figure 1.5.3.21

# SIR by Project



PROJ. NO.

Figure 1.5.3.22

# Simple Payback by Project

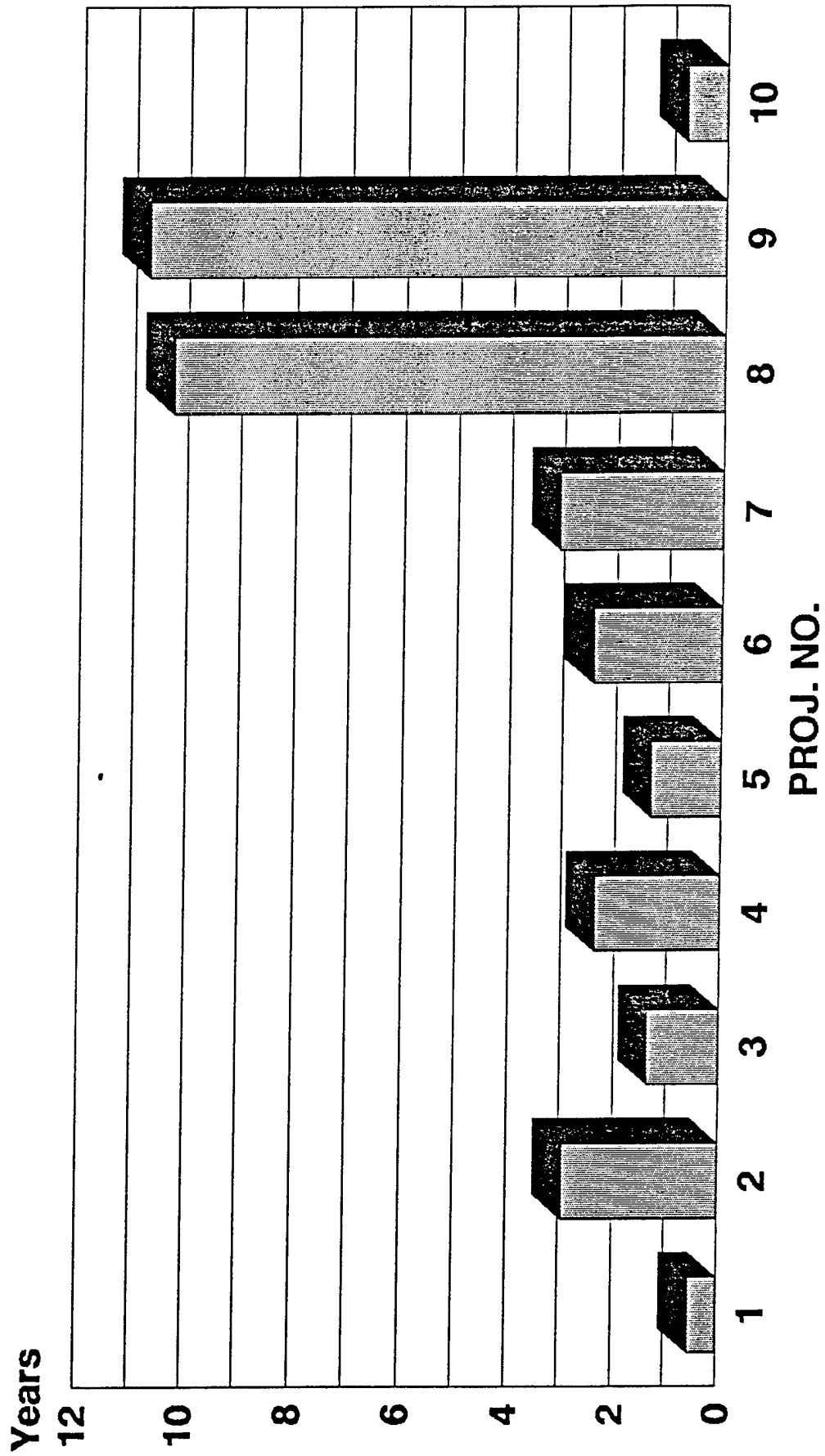
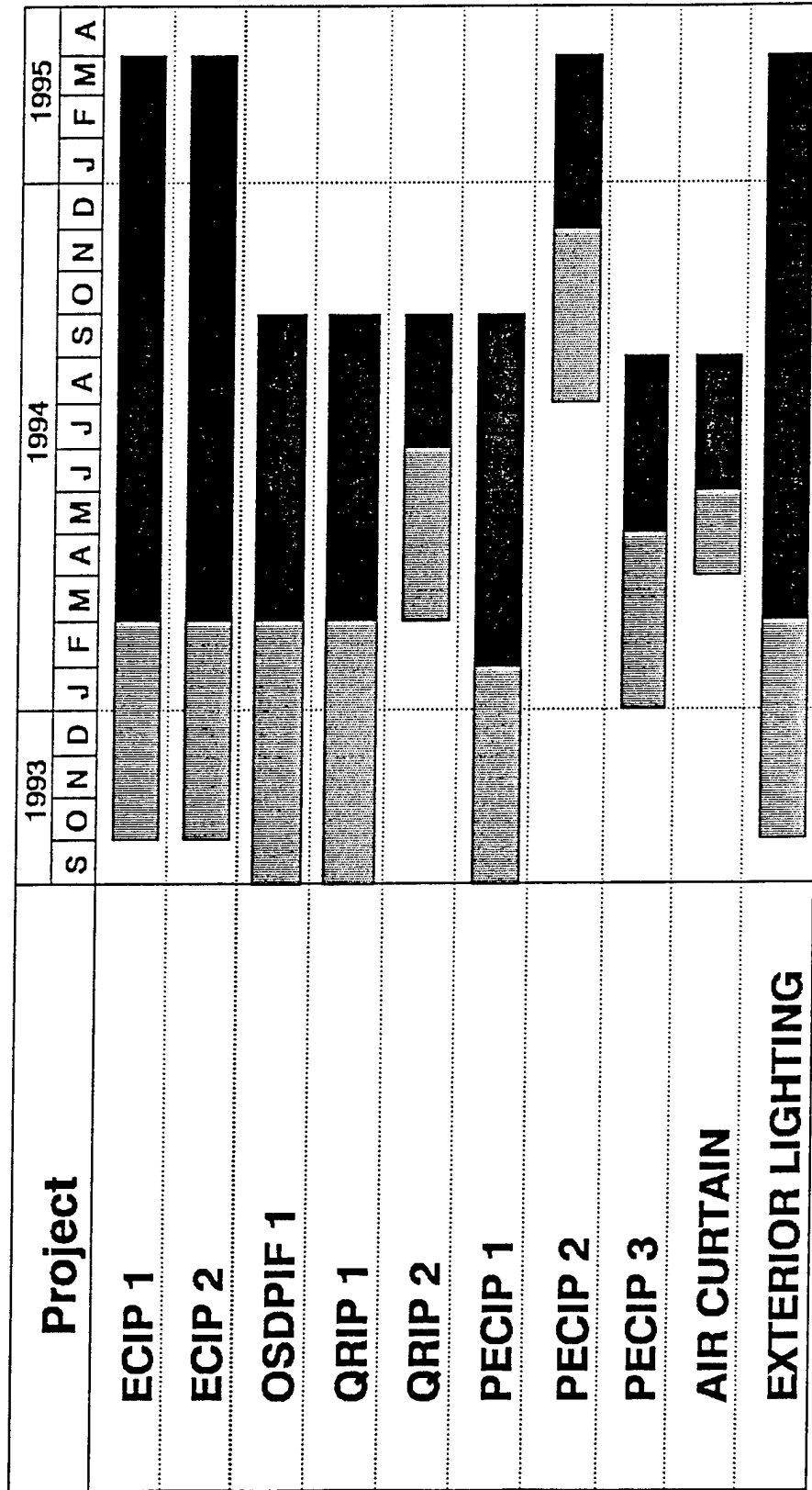


Figure 1.5.3.23

# Project Schedule



LEGEND: [Patterned Box] DESIGN PHASE [Solid Black Box] CONSTRUCTION PHASE

Figure 1.5.3.24